VOLCANIC AND COMPOSITIONAL HISTORY OF MARE NECTARIS USING CHANDRAYAAN-1 MOON MINERALOGY MAPPER (M^3) DATA. Prabhjot Kaur[1], [1]Space Applications Centre, Ahmedabad, Gujarat, India -380015, prabhjotk@sac.isro.gov.in

Introduction: Compositional studies of lunar basins and craters using hyperspectral data has brought out new information regarding the composition of lunar crust. By studying the variations in composition of mare basalts, one can trace back the volcanic history and geologic evolution of a basin and learn about lunar evolution. Several techniques and parameters exist to map, display and infer compositional variation using on hyperspectral and multispectral data. One such parameter developed using Moon Mineralogy Mapper (M^3) data is Integrated Band Depth (IBD) parameter which utilizes depth of 1000 and 2000 nm absorption along with albedo to capture overall variation in the composition based on the above mentioned absorption features [1]. Principal component analysis (PCA) and Minimum Noise Fraction (MNF) techniques are powerful tools which are widely utilized for assessing mathematical variability of large hyperspectral and multispectral data by searching the directions of variability maxima [2]. This work utilizes MNF technique to map the spectral variability and delineate various basaltic units. Cumulative crater size-frequency distributions (CSFD) technique has been used then to determine the age of emplacement of various flow units to explain the formation history of the basin.

Mare Nectaris is a multiring basin of 860 km diameter centered at 16º S, 34º E which formed around 4.1 G.a. and forms the Nectarian period of lunar chronostratigraphic system. The basin exhibits diverse geologic units, including mare basalts, dark mantle or pyroclastic deposits of volcanic origin [3]. Beaumont L, a dark haloed crater and several other craters present across Mare Nectaris are found to be rich in olivine based on the presence of 1000 nm absorption and a weak 2000 nm absorption [4]. The study identified olivine rich crater populations which may have excavated material from distinct lava flows embedded between Nectaris pyroxene rich basaltic flows.

Data set and Method: Moon Mineralogical Mapper (M^3) was an imaging spectrometer with spectral range 450-3000 nm onboard Chandrayaan-1. The data consists of 85 spectral bands and is available in two different resolutions 140m/pix from 100 altitude and 280m/pix from 200 km orbit [5]. Data imaged from 200 km orbit having spatial a resolution of ~280 m per pixel have been used to create mosaic of the basin. IBD for 1000- and 2000 nm absorption feature for Nectaris basin has been calculated using equations as mentioned in [6]. False Color Composite (FCCs) has been prepared by assigning red channel to IBD-1000, green to IBD-2000 and blue to the 1578 nm albedo channel. This color composite represents the net effect of composition, maturity and contamination by the highland materials and is widely utilized to study spectral variations of lunar surface. In this study, MNF has been applied to the M^3 mosaic of Nectaris basin and bands 2 to 8 were found to confine the information of interest while the subsequent bands are redundant and typically contain noise. Based on the visual inspection of the MNF bands, MNF 5 and 7 were found to capture the required spectral variations. False Color Composites (FCCs) have been prepared by assigning red channel to MNF 5, green to MNF 7 and blue to continuum removed 1000 nm image.

Observations and Discussions: Basalts of Mare Nectaris in IBD map display yellow to yellowish green hue, whereas the highland region surrounding the mare appears blue (Fig. 1). The basalts of SE section are slight different and display orange yellowish hue suggesting a different composition. Some of the prominent craters also display similar orange tone.

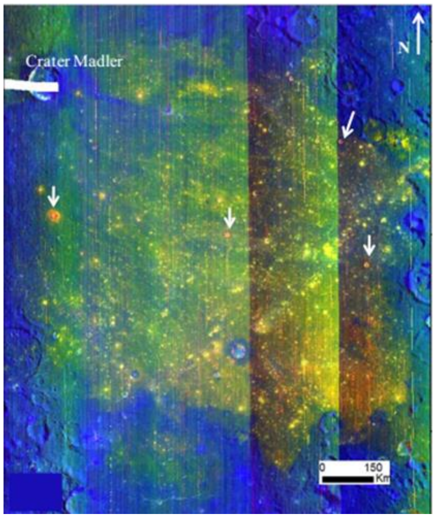

Fig. 1: IBD image of Nectaris basin.

The surface of Mare Nectaris is largely affected by the ejecta of various craters, an example of which can be seen in the NW section where ejecta from the crater Madler has blanketed the basin and is clearly seen as blue hue in the IBD map. The surface of the basin as well as the craters displays yellow hue due to pyroxenes (absorption at both 1000 nm and 2000 nm). Orange color denotes absorption at 1000 nm with weak or no absorption at 2000 nm and blue color corresponds to anorthositic/highland material or mature regions. Fig. 2 shows another FCC image generated by MNF band 5 and 7 combined with continuum removed image at 1000 nm. As can be noted from Fig. 2, spectral differences between the various regions are quite clear. Also, the spectral variability between the craters is quite enhanced in this combination. Five spectral units were delineated that collectively represents total range in composition of Mare Nectaris. The white boundaries in Fig. 2 demarcate the various spectral units mapped which are quite different from each other and display different spectral behavior. Craters present across the basin appear yellow, green and brown suggesting variation in mineralogy.

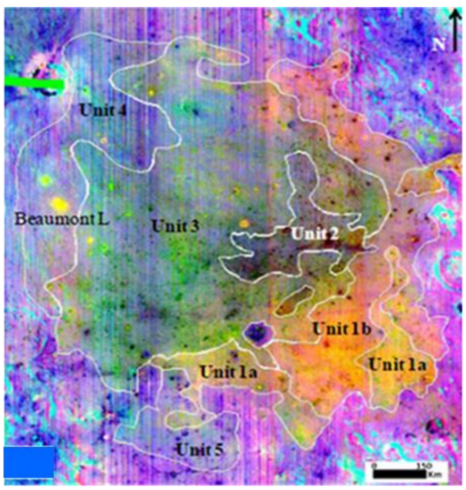

Fig. 2: MNF map generated by assigning red channel to MNF band 5, green to MNF band 7 and blue to continuum removed image at 1 µm. White boundaries represent the units delineated in this work.

The spectral variation of the Nectaris basin is well reflected in the MNF map which is used to sample the craters displaying diverse color owing to their different spectral nature. Fig. 3 shows the reflectance spectra from the areas showing different color in the MNF map with the similar color as in the MNF map.

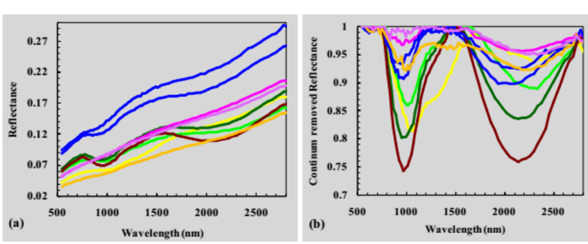

Fig. 3(a): Spectral profiles representing various colors in the MNF map. (b) continuum removed of the same. Color of spectra represents same color in the MNF map.

Based on the spectrum-color relationship interpreted above, the dominant spectral types are likely to be assigned to having petrological significance as summarized in Table 1.

Table 1: Characteristics of four distinct lithologies present in the basin

Color in the MNF map	Spectral characteristic	Dominant mineral/lithology
Blue	High albedo, with moderate absorption at 1 and 2 µm	Pyroxene bearing anorthosites
Light to dark Green	Moderate to strong absorption at 1 and 2 µm with band I depth slightly > band II depth	Pyroxenes-olivine mixture
Yellow to yellowish pink	Strong to moderate absorption at 1 µm	Olivine
Brown	Strong absorption at both 1 and 2 µm	Pyroxenes
Magenta to pink	Very weak or almost flat spectra	Mature soil

Conclusions: This study clearly brings out the spectral diversity of the Nectaris basalts which are mainly dominated by two distinct compositional flows- pyroxene rich and other is olivine rich the distribution of which is not uniform. Combining the MNF and reflectance spectra studies, it can be concluded that the basalts on the eastern flank are olivine rich. All the units mapped are completely based on the spectral analysis and the study confirms that Nectaris basaltic units are quite heterogeneous in terms of spectral variability. Age determination done by CSFD method suggest unit 1 to be younger and emplaced around 3.0 G.a. during a resurfacing event. CSFD plots also suggest volcanism in the Mare Nectaris has happened in at least two phases one near the ~3.8 G.a and later around 3.0 G.a. which provides new information on the Mare Nectaris volcanism.

References: [1] Mustard J. F. et al., (2011) *JGR, 116*, E00G12. [2] Krarmer G. Y. et al. (2011) *JGR, 116*, E00G18. [3] Whitford-Stark, J. L. (1981) *Icarus 48(3)*, 393-427. [4] Kaur P. et al., (2015) *LPSC XXXXVI*, Abstract 1973 [5] Pieters C.M. et al. (2009) *Current Science, 96(4)*, 500- 505. [6] Mustard, J.F. et al., (2011) *JGR, 116(E6)*, E00G12.